Aquatic vegetation biomass in two created riparian wetlands

Cassandra L. Tuttle and William J. Mitsch

Schiermeier Olentangy River Wetland Research Park, Environmental Science Graduate Program, The Ohio State University

Introduction

Wetlands are usually shallow and provide ideal habitat for submerged aquatic vegetation. These systems generally support diverse communities of submerged macrophytes and contain three different habitats for algal growth, including open water, illuminated solid surfaces, and the water surface (Sand-Jensen Borum, 1991). Major algal assemblages that occupy these different habitats include: phytoplankton, composed of microscopic algae entrained in the water column; epipelon, composed of motile algae inhabiting the soft sediments; epiphyton, composed of prostrate, erect, and heterotrichous algae growing on the external surface of macrophytes; and metaphyton, usually composed of filamentous green algae and associated epiphytes, which form cohesive floating and subsurface mats (Goldsborough and Robinson, 1996; Robinson et al., 1997a,b).

Wetlands are primarily noted for high emergent macrophyte production, but can also have high productivity in the water column, that may contribute significantly to total productivity (Cronk and Mitsch, 1994 a,b; Stevenson, 1996; Sand-Jensen and Borum, 1991; Robinson et al., 1997 a,b). In wetlands where sunlight penetrates through the entire water column autotrophs associated with bottom substrata need to be included for accurate measurement of primary productivity (Sand-Jensen and Borum, 1991). The contribution of different aquatic flora to aquatic productivity in wetlands varies significantly. However, these shallow-water systems provide abundant benthic substrate and are commonly dominated by submerged macrophytes and associated benthic algal assemblages that out-compete phytoplankton for nutrients (Hansson, 1998; Liptak, 2000).

Cronk and Mitsch (1994a) found that water column autotrophs, including attached and suspended algae and submerged macrophytes, contributed anywhere from 17–67 % of total net primary productivity (NPP) of created freshwater marshes in Midwestern USA, and as much as 65% of this production was due to benthic algae or submerged macrophytes rather than phytoplankton. In a study of water column productivity in a prairie lakeshore wetland Robinson et al. (1997a,b) found that concentrated thick cohesive mats of metaphyton at the water surface were the most abundant algal assemblage and contributed 60–80% of total water column productivity. Combined with epiphyton, these two benthic assemblages contributed over 98% of total algal biomass, and accounted for greater than 70% of total above ground biomass in the wetland (Robinson et al., 1997a).

Hydrology is considered the single most important environmental variable affecting aquatic metabolism because it either directly or indirectly influences all aspects of the abiotic environment affecting metabolic rates, including nutrient availability, light availability, substrate availability and water temperature (Goldsborough and Robinson, 1996, Stevenson, 1996, Sabo et al., 1999). The current velocity, water depth and stability of the water column are also important environmental variables that determine the species composition and abundance of aquatic producers in the system (Goldsborough and Robinson 1996, Stevenson 1996). The hydrodynamics of a system and the stability of the water column directly affect availability of substratum for benthic producers, and the potential for development of specific algal assemblages that characterize an aquatic producer community. Goldsborough and Robinson (1996) have proposed a model for dominant benthic algae based on four different possible hydrologic states in a wetland. According to the model, phytoplankton will likely be dominant in nutrient-rich wetlands that have high water levels and a turbulent water column (conditions that occur in wetlands during flood pulses). When wetlands are flooded consistently and characterized by a turbulent water column, but are shallow enough to support abundant submersed macrophytes, the dominant algal assemblage is commonly epiphytic. These epiphyton communities generally develop into thick metaphyton mats in sheltered areas when the water column is stable, and will persist in the absence of physical disturbance. During drawdown conditions, when the water column is extremely shallow and stable, epipelon will likely be dominant (Goldsborough and Robinson, 1996). Fluctuations in water level and flood disturbance events cause aquatic producer communities to shift between dominant species and assemblages described above.

The objective of this study was to investigate spatial patterns of aquatic vegetation biomass due to different algal assemblages and submerged macrophytic vegetation in the experimental wetlands in order to help calibrate a site specific dynamic ecosystem model (see chapter in this report). This study was carried out as part of an ecosystem-scale experiment investigating the effect of hydrologic pulsing on aquatic metabolism.

Methods

Site description

This study was carried out at the Olentangy River Wetland Research Park, a 12-ha wetland research facility located on the campus of The Ohio State University in Columbus, OH. The two 1-ha experimental wetlands examined for this study were created in 1994 and have been continuously pumped with river water from the bordering Olentangy River at an average rate of 20–30 m yr^{-1} to each. River water flows through the wetlands and then back to the Olentangy River through an outflow swale. Each wetland was designed to have 3 distinct deepwater areas, hereby referred to as the inflow, middle, and outflow basins. Over the 10 years since the wetlands were created water depth in these deepwater basins was generally 60–80 cm, while depth in remaining shallow marsh areas ranged between 20–40 cm.

In May of 1994, Wetland 1 (W1) was planted with 13 species characteristic of freshwater marshes in the midwestern USA, while Wetland 2 (W2) remained unplanted. Common emergent macrophyte species identified in the wetlands include softstem bulrush (*Schoenoplectus tabernaemontani)*, river bulrush (*Scirpus fluviatilis)*, giant bur-reed (*Sparganium eurycarpum)*, prairie cordgrass (*Spartina pectinata)*, cattail (*Typha* spp.), knotweed (*Polygonum* spp.), and rice cutgrass (*Leersia oryzoides)*. Aquatic macrophytes observed at the site during the study period include small pondweed (*Potamogetan pusillus* L.), longleaf pondweed (*Potamogetan nodosus* Poir.), curly pondweed (*Potamogetan crispus* L.), coon's tail (*Ceratophyllum demersum* L.), waternymph (*Najas* spp.), water lily (*Nymphaea* L.), and duckweed (*Lemna* L.). Previous studies at the site have identified more than 100 genera of algae, including 14 genera of cyanobacteria present in the wetlands. Dominant macroalgal populations consist of Hydrodictyon, Cladophora, Rhizoclonium and Spirogyra (Kantz and Deal, 1999), and additional filamentous genera identified in the system include Ulothrix, Microspora, Stigeoclonium, Zygnema, Bulbochaete, Mougeotia and Sirogonium (Deal and Kantz, 1997).

Sampling methods

Estimates of aquatic vegetation biomass were collected in 2005 when the wetlands were maintained with steady flow hydrology. The biomass data collected was used to help calibrate an ecosystem model developed for this site (see chapter 7 in this report). Chlorophyll-a was measured at five sites in each wetland (Figure 1) once per week in April, May and June of 2005 to estimate planktonic biomass in each deepwater basin. Water samples of 500 ml were collected in the field using dark bottles to limit light exposure. Samples were transported immediately to the onsite lab and two replicates of 50 or 100 ml from each site were concentrated according to EPA method 445.0 (Arar and Collins, 1997). Sample extraction was done according to EPA 445.0 methods without grinding (shown not to be necessary for analysis

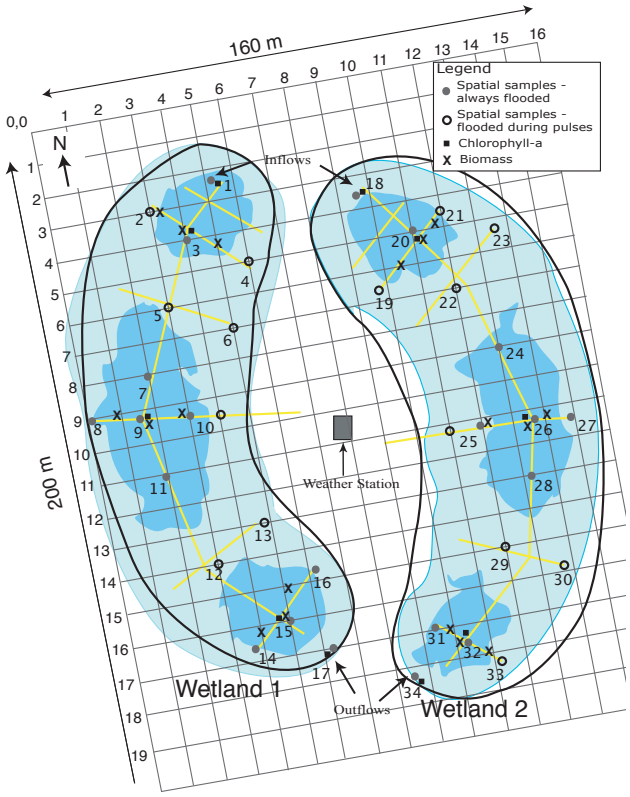

Figure 1. Site map indicating sample locations for this biomass study for chlorophyll-a and biomass. Sample locations used to estimate water column GPP are also indicated.

by Boyer et al., 1997) or acidification. Samples from June 1, 2005 were not centrifuged following extraction in 90% acetone. Samples were then analyzed for chlorophyll-a content using the Welschmeyer non-acidification method on a Turner Designs 10-AU Flourometer (Turner Designs, Inc., Sunnyvale, CA) equipped with a 10–040 R (6019) optical kit. For comparison with benthic algae and macrophytes, chlorophyll-a values were converted to grams dry weight (g dw) using a conversion factor of 0.067 g dw:mg-chl-a (Clesceri et al., 1999).

Biomass of benthic algae and submerged macrophtyes was measured one time on June 2, 2005. Biomass samples were collected using a 20-L plastic bucket with the bottom cut out (Liptak, 2000). The bucket was placed in an area with aquatic vegetation present and submersed into the sediment. Submerged macrophytes present within the bucket were carefully harvested by hand and algae were collected by hand using a fine mesh sieve. All biomass collected was placed into plastic bags and transported to the laboratory for separation and analysis. Samples were collected at three locations each in the inflow, middle and outflow basins (Figure 1) using the boardwalk as a transect, with a total of nine samples in each wetland. Biomass was washed and separated in tap water to remove sediment and invertebrate biomass, and then placed into separate pre-weighted aluminum dishes and dried in a drying oven at 60°C for more than 48 hours until a consistent weight

was achieved. After drying, samples were placed in a desiccator for at least 30 minutes and then weighed on an analytical balance to estimate total dry weight biomass. Percent cover of the algal mats and aquatic vegetation was estimated visually at the time of harvesting based on a 10 x 10 m grid system in the wetlands.

Results and Discussion

Chlorophyll-a

Mean chlorophyll-a concentration during the sample period was 7.9 ± 0.6 mg m^{-3}, which is similar to values measured in other created riparian wetlands (8 mg m^{-3}, Cronk and Mitsch, 1994a), but was low compared to wetlands with highly productive planktonic communities (Reeder, 1994). In both wetlands, chlorophyll values peaked in late Apri1 2005 and declined through May 2005 (Figure 2). In W2 there was also a second smaller peak of chlorophyll at the end of May. For W1, chlorophyll-a was highest in the river inflow water and the inflow basin. A decrease in chlorophyll from inflow to outflow was also observed in both wetlands 1994 shortly after they were created in 1994 (Wu and Mitsch, 1998). Higher concentrations of chlorophyll-a in the inflow may indicate that benthic algae in the middle and outflow basins was out-competing planktonic algae for nutrients from the water column (Hansson, 1998). This is supported by the distribution of benthic algae biomass, which was absent in the inflow basin and present in the middle and outflow basins (Figure 3a). In W2, the highest chlorophyll-a values on a sample day varied between all three basins. The higher values in the middle and outflow basins may be due to the dominance of epipelon in this wetland, which easily becomes entrained in the water column contributing to planktonic biomass (Goldsborough and Robinson, 1996).

Benthic algae and submerged macrophyte biomass

Submerged macrophyte biomass averaged 32 ± 7 g dw m^{-2} and was comprised almost exclusively of small pondweed (*Potomogetan pusillus* L.). Benthic algal biomass averaged 40 ± 8 g dw m^{-2}, and was attributable mostly to filamentous epiphyton growing on submerged macrophytes in W1 and epipelon growing directly on the soft sediment surface in W2. Algal biomass measured for this study was within ranges found previously at the site (23–136 g m^{-2}; Liptak, 2000). Due to turbulence caused by the inflow, macrophyte cover dominated the inflow basins and little to no algal biomass was seen near the inflows in either W1 or W2 (Figure 3a). This contradicts earlier studies at the site where high algal biomass was observed in the inflow basins (Wu and Mitsch, 1998; Liptak, 2000). Lack of algal biomass near the inflow during this study may be the result of the artificially high

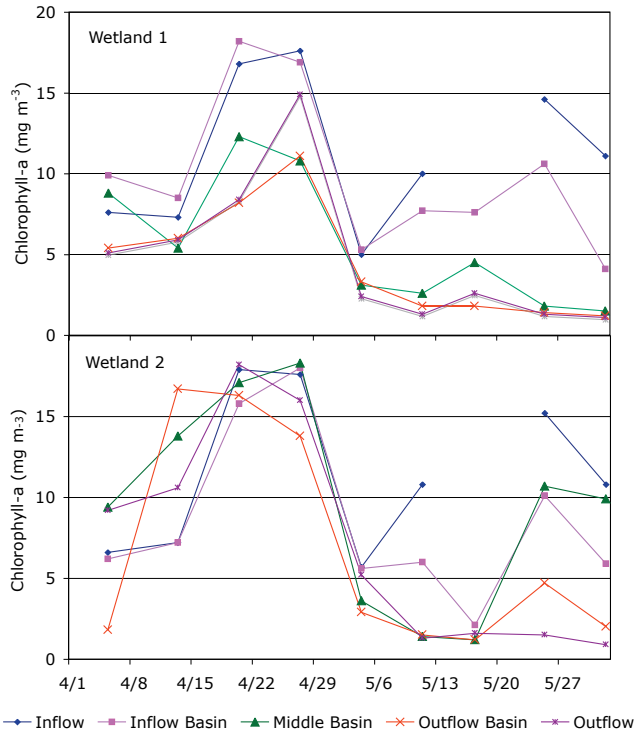

Figure 2. Chlorophyll-a measured weekly in the inflow, outflow, and each deepwater basin for Wetland 1 and Wetland 2, during sample period April–June 1, 2005.

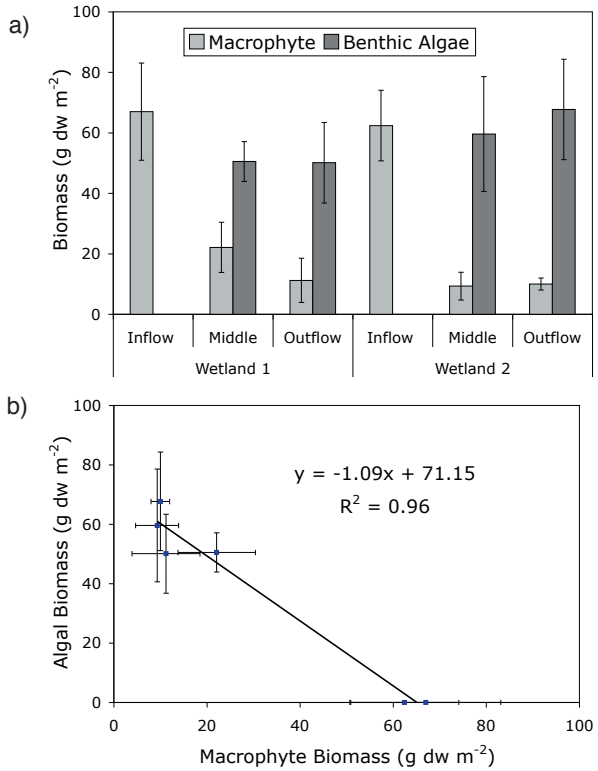

Figure 3. (a) Mean biomass for attached algae and macrophytes and (b) attached algae biomass as a function of macrophyte biomass for each of the six basins in the experimental wetlands. Error bars represent standard error.

Table 1. Summary of total biomass estimates in each basin of the wetlands for phytoplankton, benthic algae and submerged macrophytes.

	Measured Biomass g dw m^{-2}		Estimated Coverage* m^2		Total Biomass kg dw	
	W1	W2	W1	W2	W1	W2
Phytoplankton**						
Inflow Basin	0.09	0.14	950	1000	0.08	0.14
Middle Basin	0.03	0.23	2450	2650	0.08	0.62
Outflow Basin	0.03	0.05	800	800	0.02	0.04
Total					0.18	0.79
Benthic Algae						
Inflow Basin	0	0	50	300	0.0	0.0
Middle Basin	50.5	59.6	620	2550	31.3	152.0
Outflow Basin	50.1	67.7	450	800	22.5	54.2
Total					53.8	206.2
Macrophytes						
Inflow Basin	67.0	62.4	900	225	60.3	14.0
Middle Basin	22.1	9.3	2250	500	49.6	4.7
Outflow Basin	16.9	10.0	350	700	5.9	7.0
Total					115.8	25.7
Basin Total						
Inflow Basin	67.1	62.5			60.4	14.1
Middle Basin	72.6	69.1			81.0	157.3
Outflow Basin	67.0	77.7			28.4	61.2
Wetland Total					169.8	232.7

* Plant coverage was estimated visually within a day of collection.

** Calculated from chlorophyll-a concentrations using a conversion factor of 0.067 g-dw:mg Chl-a.

rate of turnover maintained in the basin to simulate steady-flow conditions with a total flow-through volume equal to when the wetlands were pulsed.

Macrophyte biomass was highest in the inflow basins and decreased as benthic algal biomass increased with distance from the inflow in both experimental wetlands (Figure 3). Benthic algal biomass was negatively correlated with macrophyte biomass (Figure 3b; $R^2 = 0.96$) when all six basins were compared. This relationship was likely due to different environmental conditions near the inflow and competitive interactions between submerged aquatic macrophytes and algae. McNair and Chow-Fraser (2003) observed a similar trend in Great Lakes coastal wetlands, where periphytic and epiphytic biomass were negatively correlated with percent cover and species richness of submerged macrophytes.

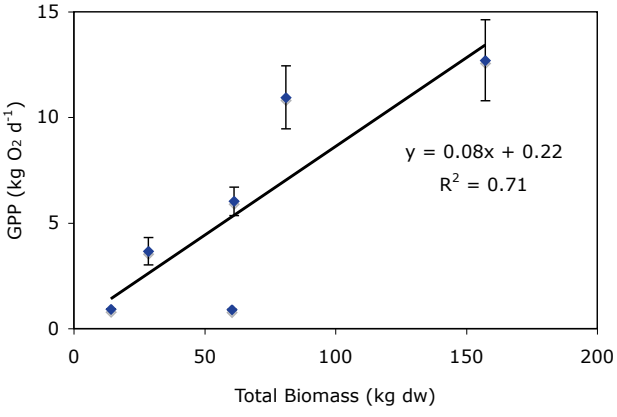

Figure 4. Mean gross primary productivity (GPP) as a function of total dry weight biomass of aquatic autotrophs for each of the three deepwater basins in the experimental wetlands. Bars indicate standard error.

Total biomass estimates

Based on the measurements summarized above, and visual estimates of plant coverage made on the day of biomass collection, the total biomass for each basin was estimated (Table 1). Phytoplankton was only a small portion of total biomass in the system at 0.17 and 0.71 kg dw for W1 and W2, respectively. Total benthic algal biomass (including epiphyton, metapyton and epipelon) was 54 kg dw for W1 and 206 kg dw for W2. These values were comparable to metaphyton biomass measured in the basins at the end of May in 1999, (192 kg dw for W1 and 74 kg dw for W2; Liptak, 2000). However, in 1999, W1 had higher biomass values than W2, while the reverse was true in 2005. Total submerged macrophyte biomass was 116 and 26 kg dw for W1 and W2, respectively.

The total biomass estimate for each basin was compared to the mean GPP calculated for that basin on the same day, and was linearly correlated (Figure 4: $R^2 = 0.71$). This indicates that GPP was related to total biomass in the system, and supports modeling methods of simulating GPP as a function of biomass in the basin.

Conclusions

Similar species of sumberged aquated macrophytes were present in both wetlands but different algal assemblages were observed in each: W1 was dominated by filamentous epiphyton while W2 was dominated by epipelon. Because similar hydrology has been maintained in both wetlands since they were created, other environmental variables such as soil composition, emergent vegetation community, and hetertroph communities must also play a significant role in determining dominant algal assemblage and aquatic productivity.

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